COUPLING CHARACTERISTICS BETWEEN DIELECTRIC DISK AND RING LOCATED IN AN ECCENTRIC CONFIGURATION

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ABSTRACT

Whispering Gallery (W.G.) mode coupling characteristics between a novel configuration of dielectric disk and ring waveguide, are analyzed and investigated. The theoretical results of coupling coefficients and field distributions are obtained by solving a mode-coupled equation which is derived from the Lorentz's reciprocity theorem and divergence theorem. Experimental result of field distribution is compared to the theoretical one, they agree with each other well.

INTRODUCTION

W.G. mode dielectric resonators have received considerable attention of many designers of millimeter wave integrated circuits[1]-[4]. Advantages offered by these kinds of resonator, such as good field concentration, high quality factor, and adoptability to integrated circuit, lead to realize excellent performance of millimeter through optical wave oscillators and filters [2].

In the past several years we have studied several different shapes of W.G. mode dielectric resonators, such as a circular disk, ring, elliptic disk, and coaxial ones[5]-[7]. In order to develop the analytical way of the W.G. mode dielectric resonator, we consider the resonator which has relatively large dimension compared to a handling wavelength. In the preceding study in this series we find that there are a lot of resonant modes existing in the large dimensional resonator and its Free Spectral Range (FSR) is too narrow to use practically . Thus the performance of the filter using a single large W.G. mode dielectric resonator is poor in general. To obtain better performance, a combined resonator coupled by more than two single resonators may be used. In this way, the FSR can be expanded to the Least Common Multiple(L.C.M.) of the individual coupled resonators [8]. As a result, we can expect to obtain relatively broad band filter using this configuration.

For the case of using two coupled dielectric resonators, it is the most important to understand the coupling characteristics between the coupled individual resonators.

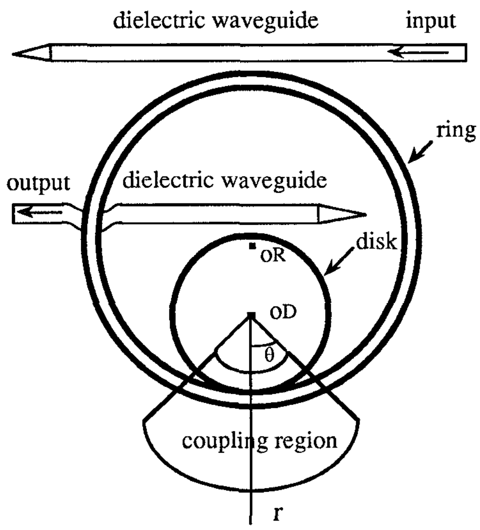

Fig.1 Coupled dielectric resonators

In this paper, we propose a novel configuration made from W.G. mode dielectric disk and ring, shown as figure 1. Unlike traditional configuration in which two dielectric disks or rings are arranged in cascade or side by side[3], we put the disk into the ring to form a eccentric structure. It is obvious that the coupling quantity between disk and ring can be controlled easily by changing the dimension of disk

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or ring. Additionally, this eccentric configuration occupies so smaller area compared with that of traditional ones that it is very suitable for integrated circuits.

As the first step to realize a filter, we concentrate our attention to investigate the coupling characteristics between disk and ring arranged in the eccentric configuration here. An analytical method for coupling characteristics of the structural waveguide modes will be presented. The coupled mode equation based on the Lorentz's reciprocity theorem and divergence theorem is solved to obtain the theoretical coupling coefficients and coupled field distribution around the coupling region. Experimental result of field distribution is also shown and compared to the theoretical one. As a result of this paper, we expect to find the proper analytical approaching and apply it to the millimeter through optical wave integrated circuits in the future.

ANALYSIS

Coupling Structure

Figure 2 shows the coupling region between disk and ring placed in an eccentric configuration. We choose cylindrical coordinate system as shown in figure 2. In fact, this choice has made analysis procedure to be very simple compared to rectangular coordinate system [9]-[10].

In figure 2, R1 is radius of the disk. R2 and R3 are radii of the ring. εr is relative permittivity of the disk and ring. $\varepsilon 1$ is that of the other area.

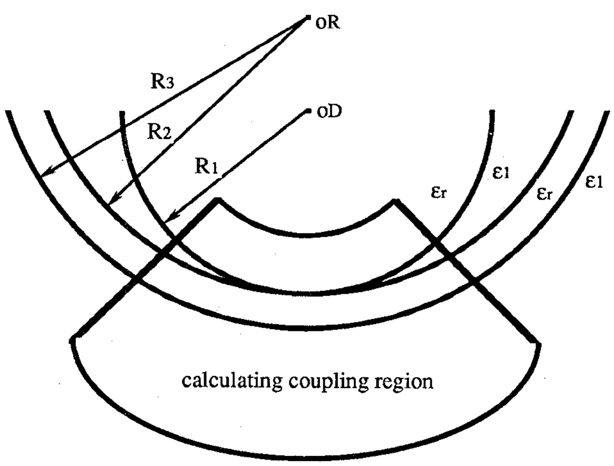

Fig.2 Coordinate and coupling region

Coupled-Mode Equation

To evaluate the coupling coefficients, first of all we have to relate the disk with ring under the coordinate system. Next, we express a total coupled field around the coupling region by linear combination of modal fields of the individual waveguides with weight functions $m_p(\theta)$, $m_q(\theta)$ [9]-[10]. The Lorentz's theorem and divergence theorem are applied to two sets of field combination, i.e. the total coupled field and individual guided modal fields. Finally, for the weight functions, we obtain a coupled mode equation in which the coupling coefficients $k_{ij}(i,j=1,2)$ vary along the coupling mechanism.

$$\begin{bmatrix} \dfrac{\partial m_p(\theta)}{\partial\theta} \\ \dfrac{\partial m_q(\theta)}{\partial\theta} \end{bmatrix} = \begin{bmatrix} k_{11}(\theta) & k_{12}(\theta) \\ k_{21}(\theta) & k_{22}(\theta) \end{bmatrix} \begin{bmatrix} m_p(\theta) \\ m_q(\theta) \end{bmatrix}$$

NUMERICAL RESULTS

Coupling Coefficients

As the result of solving the coupled mode equation, we show the coupling coefficients between the coupling structure in figure 3. Unlike parallel coupler, the nonparallel one presents the complex coupling coefficients. The coupling coefficients vary with propagating direction.

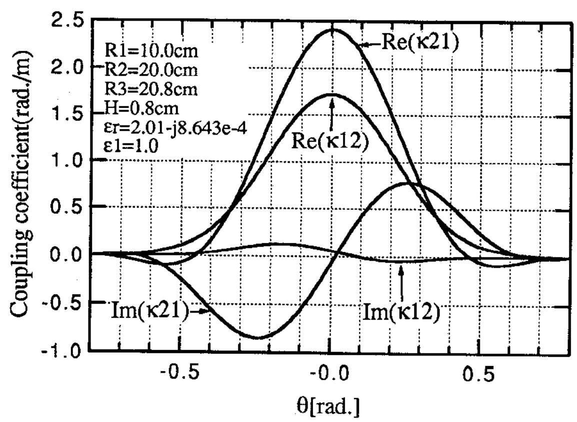

Fig.3 Coupling coefficients of the system

Coupled Field Distribution

A numerical result of the coupled field distribution around the coupling structure is shown in figure 4. The contour lines are drawn every 2.5 dB in amplitude. In this calculation the ring is excited at $\theta = -\pi/4$ [rad.]. In the positive z region, a W.G. mode field appears on the disk.

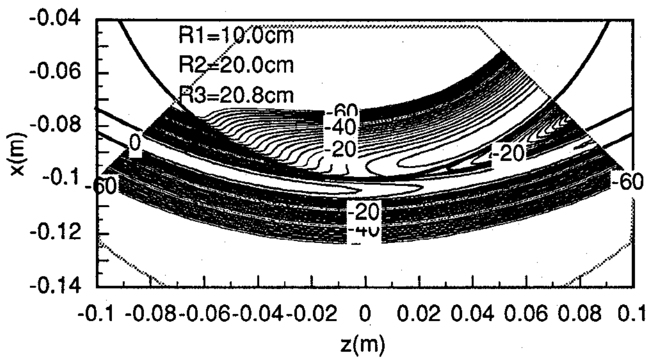

Fig.4 Electric field distribution of the coupled system (ring is excited)

EXPERIMENT

In order to verify the theory derived in this paper, an experiment is carried out . The employed coupling structure has the same dimensions as calculated one. The measured result of coupled field distribution is shown in figure 5. It is found that the measured result is in good agreement with the calculated one shown in figure 4.

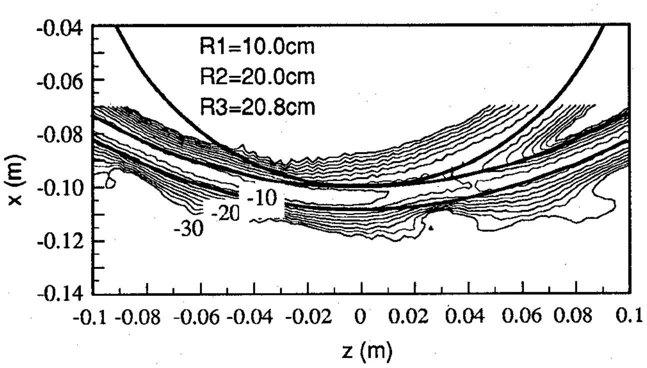

Fig.5 Experimental result of electric field distribution of the coupled system (ring is excited)

CONCLUSIONS

The analytical method for coupling characteristics of dielectric disk and ring in eccentric configuration is developed. By establishing the coupled mode equation based on the Lorentz's reciprocity theorem and divergence theorem, we can compute the coupling coefficients and coupled field distribution around the coupling region accurately. The measured result of coupled field distribution is presented and also compared with the calculated one. They agree with each other well. The proper analytical approaching presented in this paper will be applied to design a directional filter in the millimeter wave integrated circuits in the near future.

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